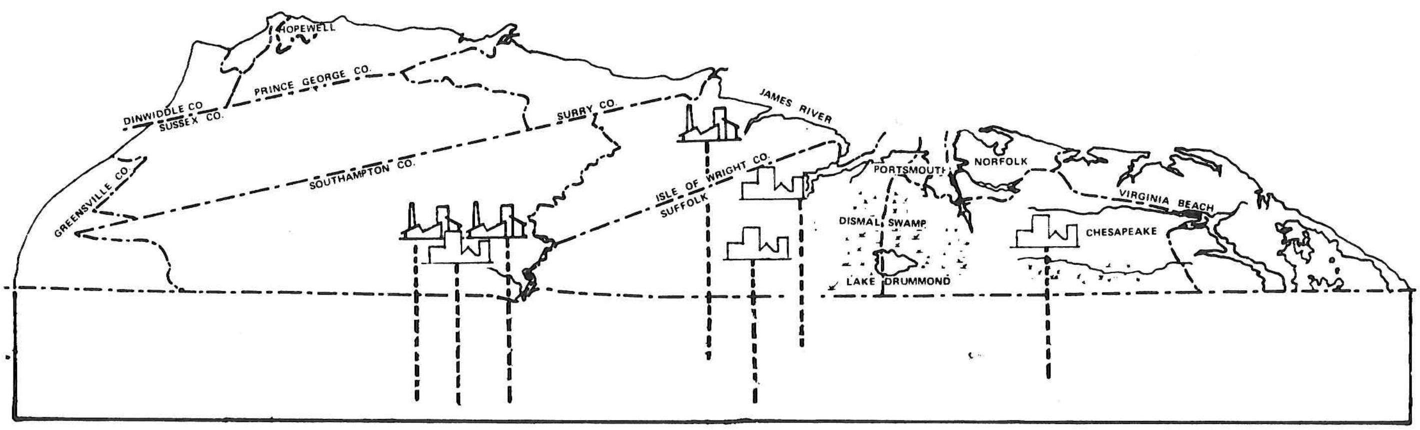
GROUNDWATER OF SOUTHEASTERN VIRGINIA



VIRGINIA STATE WATER CONTROL BOARD

BUREAU OF WATER CONTROL MANAGEMENT

RICHMOND, VIRGINIA

PLANNING BULLETIN 261-A

AUGUST 1974

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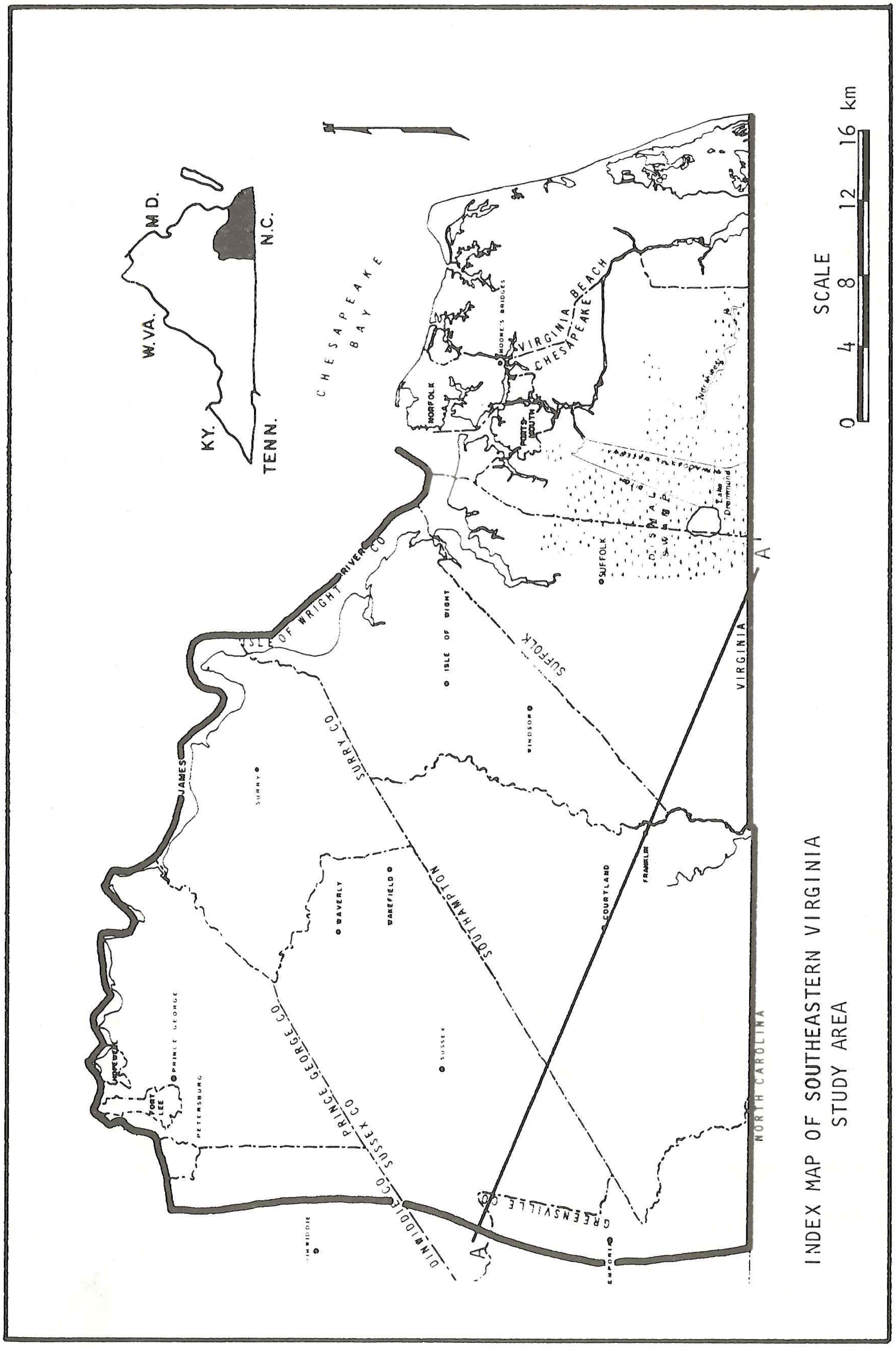
CHAPTER I

INTRODUCTION

From 1941 to present (1974), large industrial withdrawals of groundwater in the Franklin area have produced a cone of depression approximately 32 kilometers (km) in diameter and 55 meters (m) deep. Withdrawals at Franklin and elsewhere in southeastern Virginia have raised concern over current and future development and utilization of groundwater.

The southeastern Virginia study area includes all of Isle of Wight, Prince George, Southampton, and Surry counties, parts of Dinwiddie, Greensville, and Sussex counties, and the cities of Chesapeake, Emporia, Franklin, Hopewell, Norfolk, Petersburg, Portsmouth, Suffolk, and Virginia Beach (Plate No. 1).

Many reports have been written on the geology and groundwater resources of southeastern Virginia. Sanford (1913) briefly summarized the geology and groundwater conditions in the Franklin area. One of the most comprehensive reports was by Cederstrom (1945) in which he described the geology and the groundwater pumpage and levels in southeastern Virginia. Sinnott (1968) reported on yield tests conducted during 1949-1950 to determine the aquifer coefficients of the Potomac Group. The Virginia Division of Water Resources (1970) outlined the groundwater problems of southeastern Virginia and a proposal for groundwater legislation and management. The most recent report was by Brown and Cosner (1973) who discussed the groundwater conditions in the Franklin area.



Source: Virginia Division Water Resources (1970) PLATE NO. 1

CHAPTER II

HYDROGEOLOGY

Aquifer Systems

The Virginia Coastal Plain consists of a seaward-thickening wedge of sands, silts, clays, and marls deposited by fluvial, deltaic, and marine processes on top of a pre-Cretaceous basement complex. The geologic formations are, from oldest to youngest, the Cretaceous Potomac Group, the Eocene Pamunkey Group and Chickahominy Formation, the Miocene Chesapeake Group, the Pleistocene Columbia Group, and Recent sediments. A brief lithologic description of these geologic units is given below and in Table No. 1; a generalized geologic cross-section of southeastern Virginia is shown in Plate No. 2. For a more detailed discussion of the hydrogeology of southeastern Virginia, see Sanford (1913) and Cederstrom (1945).

For purposes of this report, the concept of an aquifer system, rather than a geologic formation, was employed. An aquifer system consists of a hydrologic unit which is both sufficiently uniform and unique over a large area such that it may be distinguished from other hydrologic units. The aquifer system considered in this study has very nearly the same boundaries as the Lower Cretaceous Potomac Group, which consists of interbedded sands, silts, and red clays of deltaic origin.

The sands and gravels of the Potomac Group are irregularly shaped, areally limited channel sediments deposited within a deltaic complex. The sands are surrounded mainly by silts which were deposited in flood plains and in interdistributary areas of the deltaic complex. Although

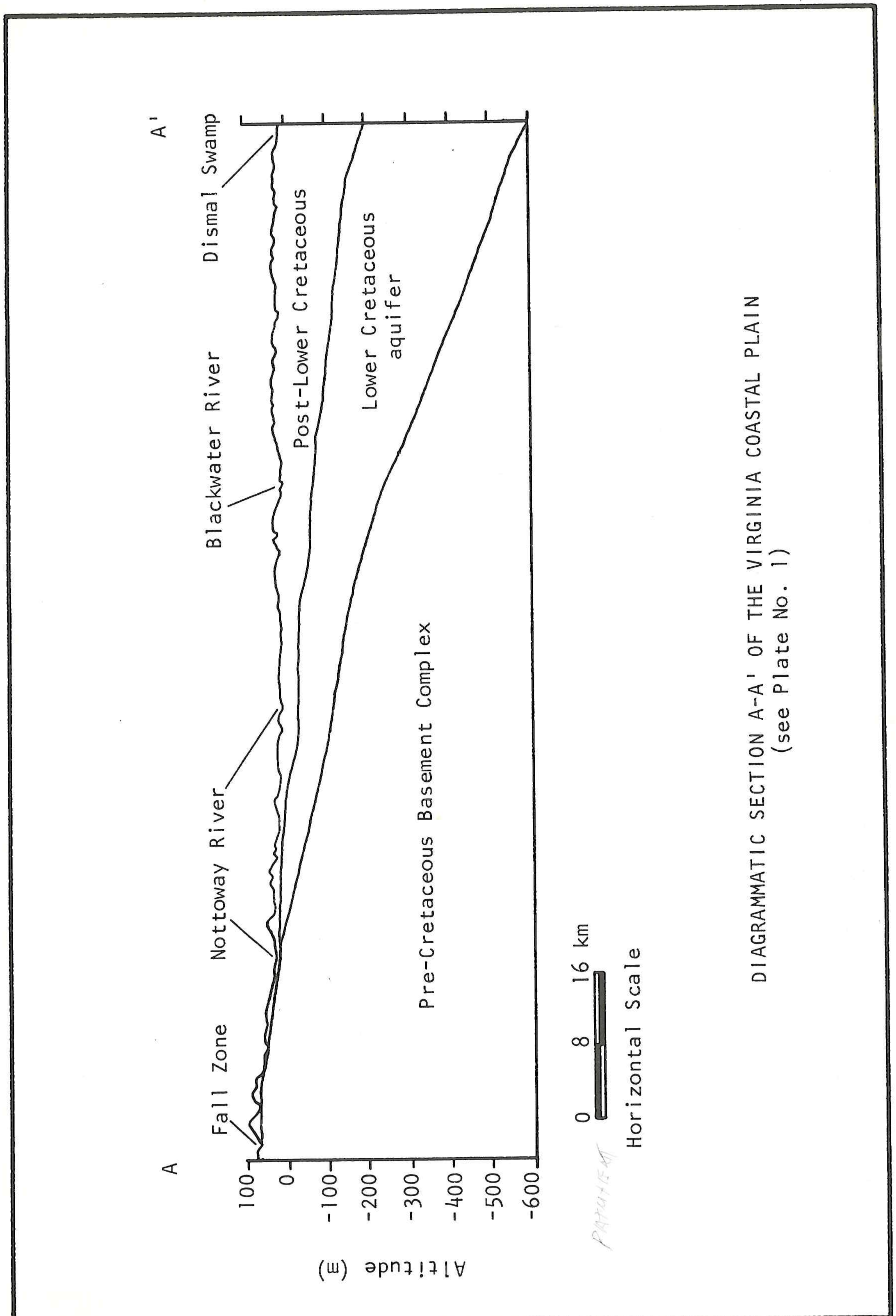
TABLE 1

GEOLOGIC UNITS AND THEIR WATER-BEARING CHARACTERISTICS

SYSTEM	SERIES	FORMATION	AQUIFER DESIGNATION IN THIS REPORT	* APPROXIMATE THICKNESS METERS	LITHOLOGIC CHARACTER	HYDROLOGIC COMMENTS
QUATERNARY	RECENT AND PLEISTOCENE		Upper Aquifer	11	Unconsolidated sand, clay, gravel, and loam of fluvial and marine deposition. Surficial terraces and dunes.	Sand and gravel aquifers yield quantities adequate for domestic and small industrial demands. Used extensively as a domestic source. Nonartesian aquifer.
TERTIARY	MIOCENE	CHESAPEAKE GROUP: YORKTOWN, ST. MARYS, CHOPTANK, CALVERT	Upper Aquifer	149	Sand, blue and gray clay, marl, and coquina. Marine deposition.	Yorktown formation is the principal aquifer. Yields are adequate for domestic use, small public supply systems, and small industrial demands. Frequently used by housing developments. Nonartesian aquifer.
TERTIARY	EOCENE	CHICKAHOMINY	Upper Aquifer	14	Blue, gray, and brown clay with glauconite Marine deposition.	Aquia formation is the principal aquifer. Yields are adequate for moderate industrial demands. Quality is generally poor. Aquifer infrequently used as a water supply. Artesian aquifer.
TERTIARY	EOCENE	PAMUNKEY GROUP: NANJEMOY, AQUIA	Upper Aquifer	14	Sand, clay, and marl with glauconite. Marine deposition.	Aquia formation is the principal aquifer. Yields are adequate for moderate industrial demands. Quality is generally poor. Aquifer infrequently used as a water supply. Artesian aquifer.
CRETACEOUS	UPPER CRETACEOUS	MATTAPONI ?	Lower Aquifer (Principal Aquifer)	27	Clay, sand, and marl with glauconite. Some induration of sand and clay. Predominately of marine deposition.	Aquifers yield quantities adequate for moderate industrial demands. Aquifers are infrequently used as a water supply. Chloride content increases rapidly east of Suffolk. Artesian aquifer.
CRETACEOUS	LOWER CRETACEOUS	POTOMAC GROUP: PATUXENT	Lower Aquifer (Principal Aquifer)	133+	Arkose sand, gravel, clay are interbedded and lenticular. Great lateral variation with beds thickening, thinning or pinching out in short distances. Plant material is present. Continental deposition.	Excellent aquifers producing quantities adequate for large industrial demands. Chlorides increase rapidly east of Suffolk. Artesian aquifer.
PRE-CRETACEOUS		BASEMENT COMPLEX	NONE		Granite, gneiss, and other metamorphic rocks.	Yields are adequate for domestic and small industrial demands. Frequently used along Fall Zone.

*NOTE: FROM E-LOG OF WELL 217-1 IN NORFOLK

Source: Virginia Division Water Resources (1970)



DIAGRAMMATIC SECTION A-A' OF THE VIRGINIA COASTAL PLAIN
(see Plate No. 1)

Source: Brown and Cosner (1973)

PLATE NO. 2

the silt deposits are more regular and more extensive than the channel sands, they also are discontinuous. The permeability of the silt deposits is too low for aquifer development; it is high enough, however, to allow substantial recharge to adjacent sands and gravels. The clays of the Potomac Group were deposited along the delta fringes and in interdistributary lagoons and swamps. The clays also are limited in areal extent.

The Potomac Group, therefore, contains discontinuous bodies of high-yield sands which are connected by fairly transmissive silts and only partially are isolated by a clay bed. In this situation, vertical recharge to the aquifers from overlying deposits may well exceed horizontal recharge from the small outcrop areas of the Potomac Group along the Fall Zone.

The upper boundary of the lower aquifer system was determined in a somewhat arbitrary manner. Nearly all available geophysical logs show that a fairly continuous zone of fine-grained material overlies the lower aquifer system. This zone conforms with the top of the Lower Cretaceous aquifer near the Fall Zone but apparently diverges to the east upward from the top of the Lower Cretaceous sediments. Although the fine-grained material is not everywhere present, and may in fact be several unconnected layers, it apparently is persistent enough to cause an aquifer pressure differential between the upper and lower aquifer systems and undoubtedly has sufficient transmissivity to allow recharge of the lower aquifer system from the upper aquifer system. This boundary zone probably conforms with the Upper Cretaceous deposits which Cederstrom (1945) described as clays and their equivalents which were persistent over a wide area, but which varied greatly in lateral continuity and in thickness.

The upper aquifer system consists of the deposits of the Eocene Pamunkey Group and Chickahominy Formation, the Miocene Chesapeake Group, the Pleistocene Columbia Group, and Recent deposits.

The Pamunkey Group consists of thin, lenticular glauconitic sands and some clay and marl interbeds. In general, the Pamunkey Group easily allows the vertical migration of groundwater.

The Miocene Chesapeake Group is composed of clays, sandy clays, marls, and some sands. This group occurs near the surface throughout most of the southeastern Virginia Coastal Plain. To the east the Chesapeake Group overlies the Pamunkey Group, and near the Fall Zone it overlaps both the Pamunkey Group and much of the Potomac Group. The Chesapeake Group permits vertical recharge of lower aquifers along the Fall Zone and further to the east where the Potomac aquifers are pumped heavily.

The Pleistocene Columbia Group consists of terraces, fluvial, and flood plain deposits. This unit also permits vertical movement of groundwater.

Recharge

The principal water-bearing sediments of the study area are the thick sands and gravels in the Potomac Group of Lower Cretaceous age. In the Franklin area, aquifers of this group are encountered from approximately 130 m below land surface to the Triassic shales or pre-Cretaceous crystalline rocks approximately 380 m below land surface.

Recharge to the Potomac aquifers partially occurs in the small outcrop area along the western edge of the Coastal Plain near the Fall Zone. The decline in the piezometric levels and the resultant increase in pressure differentials have caused leakage from the overlying clays and sands into the heavily pumped Cretaceous aquifers. The groundwater levels in the overlying Eocene and Miocene aquifers historically have declined, although they have not been pumped heavily.

The quantity of water derived from vertical leakage from the sediments overlying the Potomac aquifers is probably much greater than the quantity of water recharged to artesian storage from the outcrop area along the Fall Zone. The rate of water movement downward into the Potomac aquifers is determined by the head differential of the overlying beds and the effective vertical permeability. Although the vertical permeability of the silt and clay beds is small, these beds generally are discontinuous, and each aquifer probably is connected to both the overlying and underlying aquifer by a substantially permeable material.

Also, water moves directly through clays of low permeability. For example, the leaky confining bed of silty clay overlying the Potomac aquifers is approximately 15 m thick in the Franklin area. The permeability is estimated to be 0.008 $m^3/d/m^2$. Such a material was described by Wenzel (1942) to be 49 percent by weight clay and 45 percent silt. By assuming a head difference of 1 m between the aquifer above and below the silty clay bed and by using Darcy's Law

$$Q = PIA$$

where Q = recharge in m^3/d through a specified area of the confining bed, P = vertical permeability of silty clay confining bed, I = hydraulic gradient imposed on confining bed = 1 m/m, and A = specified area of silty clay confining bed through which percolation occurs.

Therefore, leakage through the silty clay bed of one square km is calculated as follows (example adopted from Ferris and others, 1962, p. 111):

$$Q = 0.008\ m^3/d/m^2 \times 1\ m/m\ (1000\ m)^2 = 8000\ m^3/d.$$

This volume may not be precise for the Franklin area but is intended to show the order of magnitude of vertical leakage into the Potomac aquifers.

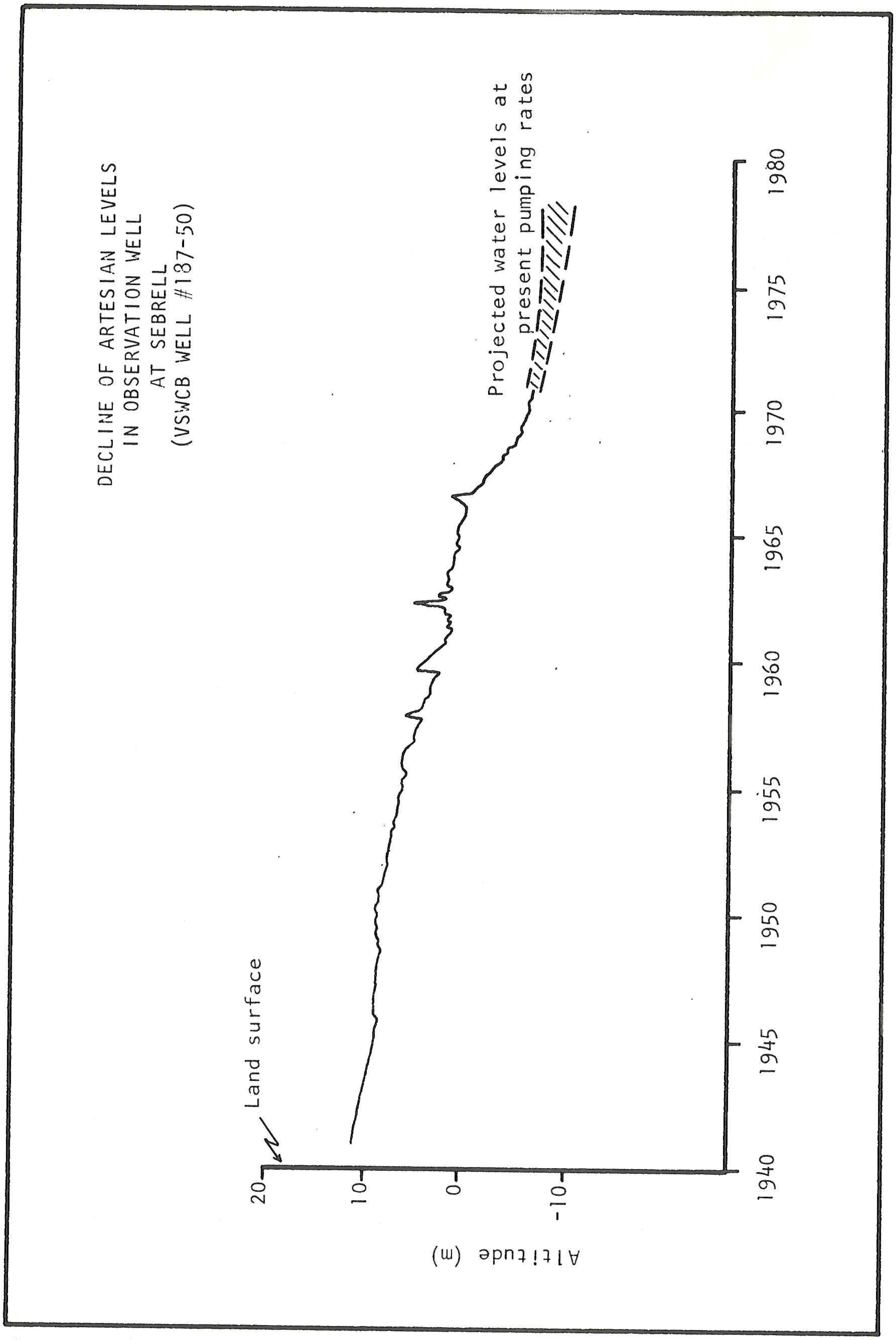
The water derived from the overlying sediments in areas of concentrated pumpage has prevented water levels of the Potomac aquifers from declining more significantly.

Discharge from water-table aquifers (unconfined aquifers) to all surface-water systems, including the Dismal Swamp, occurs during low-rainfall periods when the groundwater levels still are high. During high-rainfall periods surface-water bodies recharge the groundwater system. For a detailed report on the Dismal Swamp, refer to Lichtler and Walker (1974).

Water Level Declines

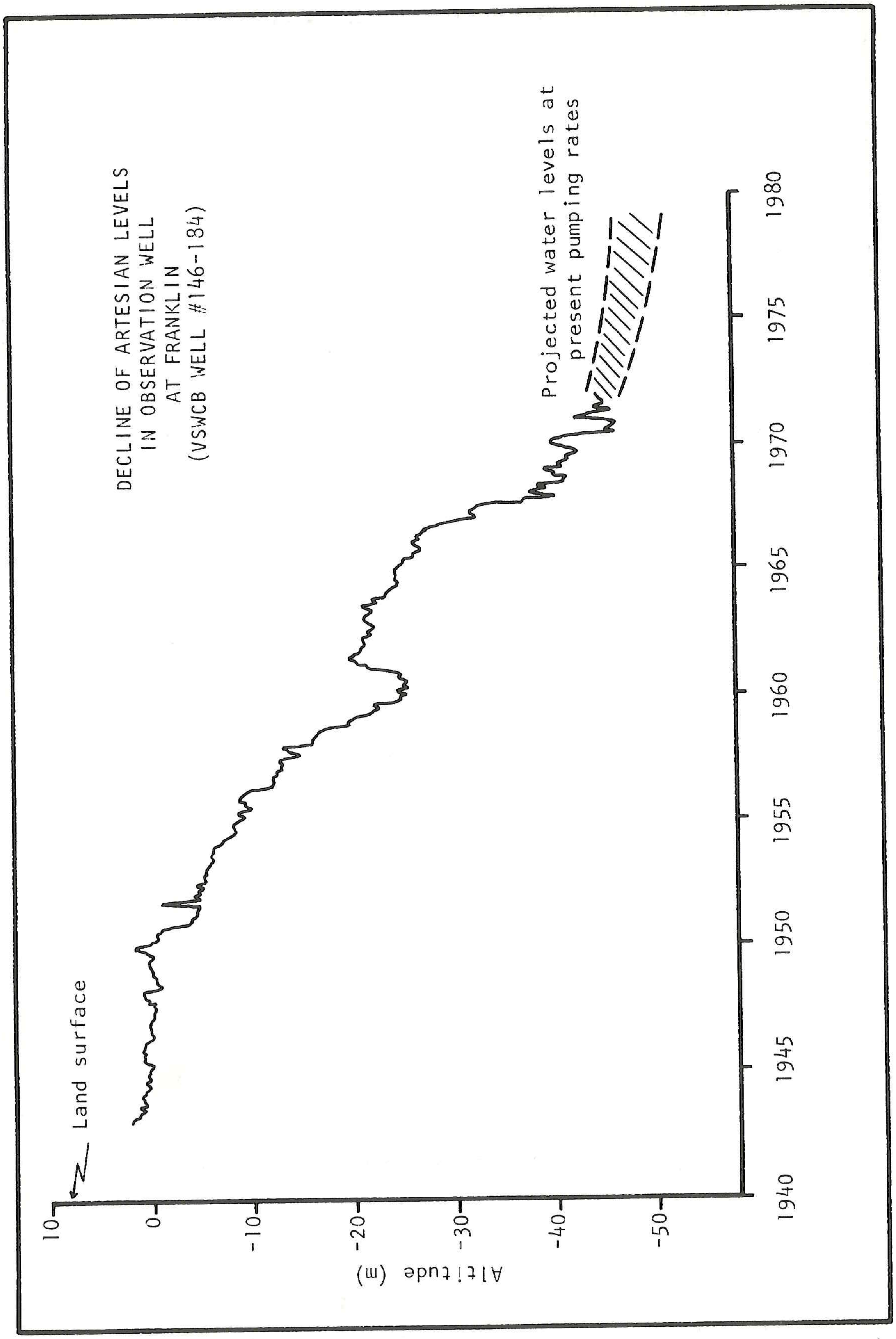
Sanford (1913) reported that in most areas of Southampton County the level of artesian waters in the Potomac sands were 8 to 15 m above mean sea level (msl) in 1913. These levels were recorded prior to heavy withdrawals and areal declines. Currently water levels of the Potomac aquifers near Franklin are approximately 52 m below msl, declining 60 to 67 m from the original surface.

The longest historical record of levels in southeastern Virginia is the Virginia State Water Control Board (VSWCB) well #187-50 at



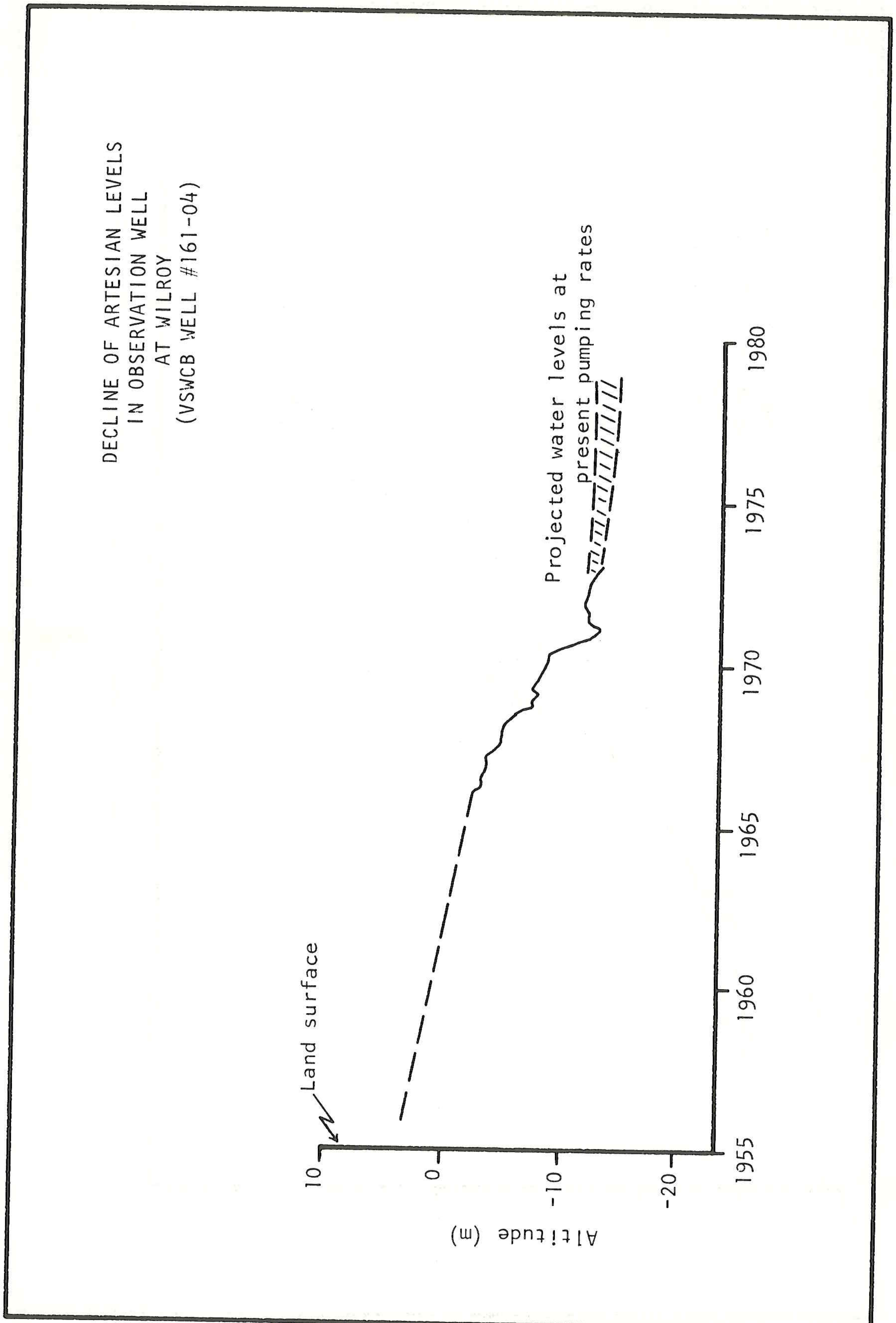
Source: Virginia State Water Control Board-BWCM

PLATE NO. 3

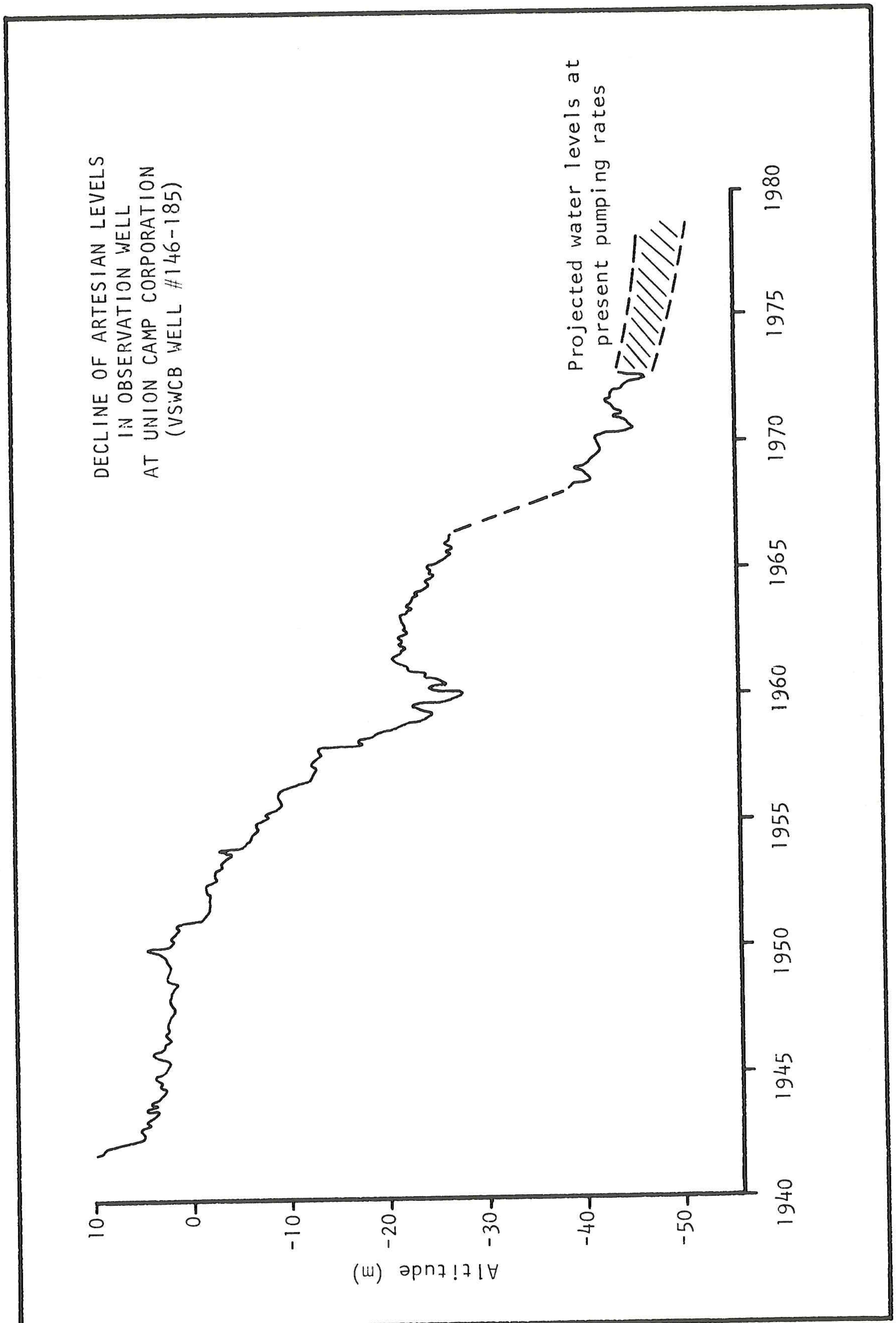


Source: Virginia State Water Control Board-BWCM

PLATE NO. 4

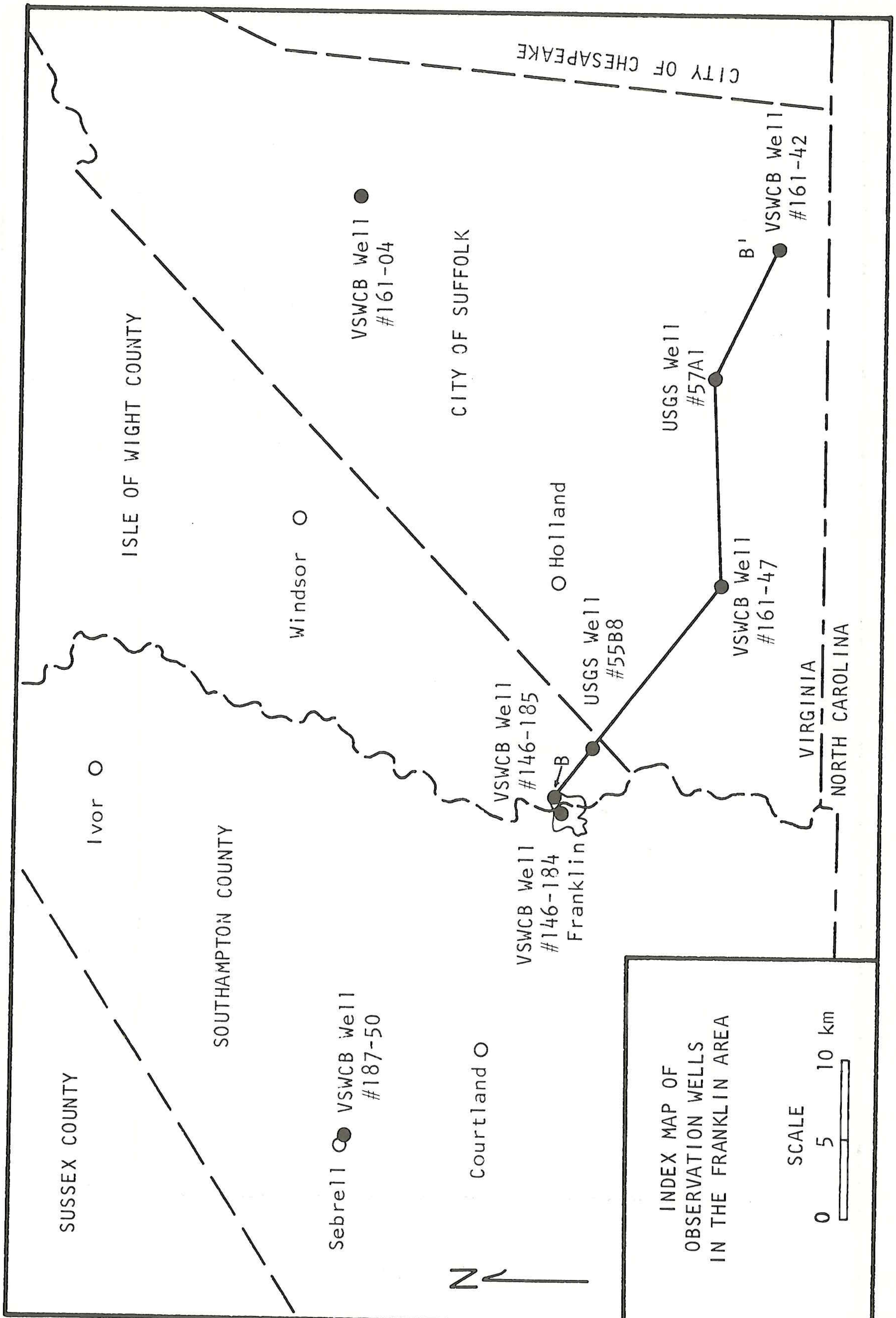


Source: Virginia State Water Control Board-BWCM PLATE NO. 5



Source: Virginia State Water Control Board-BWCM

PLATE NO. 6



Source: Virginia State Water Control Board-BWCM

PLATE NO. 7

Sebrell in Southampton County (Plate No. 3). This well is approximately 24 km northwest of Franklin and was developed in the Potomac aquifers. In 1908 the water level was 14.3 m above msl; in 1971 the level had declined to 6.4 m below msl. The VSWCB well #146-184 (Plate No. 4) located near Franklin was developed in Lower Cretaceous Potomac sands and declined 30 m between 1941 through 1960 (also Plate No. 5, Plate No. 6, Plate No. 7).

Cederstrom (1945) reported a head 6 m above msl at P. H. Dole's well near Zuni (Isle of Wight County) in 1927. This well is approximately 24 km from Franklin and was developed in Lower Eocene or Upper Cretaceous aquifers. Leggette, Brashers, and Graham (1964, unpublished) found the water level in that well to be 2 m below msl in 1964, a net decline of 8 m. Other comparisons of wells developed in the upper aquifers which have not been pumped heavily show similar declines, which result from leakage into the lower, heavily pumped Potomac sands.

Cone of Depression at Franklin

Water which enters the pore space of the Virginia Coastal Plain sediments moved downward and eastward to the coast before major pumpage began (1892) in the area. In the Franklin area, groundwater now flows into a cone of depression produced by the heavy groundwater pumpage in that area. The cone presently extends westward to the Fall Zone, southward into North Carolina (approximately one-third of the cone of depression centered at Franklin occurs in North Carolina), and merges with smaller cones of depression to the north and to the east (Brown and Cosner, 1973).

Between 1939 and 1968 approximately 1.9 billion m^3 of water were